Amendments to the Specification

Please insert the following into the specification on page 4, line 28:

Ion beam sputtering or ion beam deposition (IBD) enables to achieve high quality photo mask blanks of all types.

A photo mask blank, in particular a binary photo mask blank, a phase shifting photo mask blank or an extreme ultra violet photo mask blank is manufactured by providing a substrate and a target in a vacuum chamber, providing a first particle beam in the vacuum chamber and emitted from a first particle source or deposition source, sputtering said target by irradiating with said first particle beam and depositing at least a first layer of a first material on said substrate by said sputtering of said target.

With ion beam sputtering the first ion beam is directed onto the target. Thereby material or particles, e.g. atoms or molecules being sputtered from the target emerge from said target in direction to said substrate and are growing a layer or film on the substrate or on another layer or film already existing on the substrate.

Preferably, the photo mask blank is directly irradiated by a second particle beam emitted by a second particle source or assist source, which is different from the deposition source. In, particular, the second particle beam is directed onto said photo mask blank, i.e. directly onto the substrate or directly onto one of said films deposited on the substrate. The second ion beam is preferably an ion beam too. However, for some applications it could also be an electron beam.

Preferably, irradiating said photo mask blank comprises irradiating said substrate and/or said first film and/or further deposited films before and/or after said step of depositing said film or films. Advantageously irradiating said photo mask blank by said second particle beam provides a large variety of treatment possibilities to improve the quality and performance of the photo mask blank.

Preferably, the target and/or the substrate are mounted rotably or pivotably. By this, the system is adjustable to hit the target under an angle >0 degree, particularly >10 degree with

respect to a target normal line by the first particle beam. Further preferably, the substrate defines a substrate normal line and sputtered particles from the sputter target and/or said second particle beam hit said photo mask blank, i.e. the substrate or a further film under an angle >0 degree, particularly >10 degree to the substrate normal line.

Advantageously, the photo mask blank provided has a very low value of film stress of about 0.2 MPa or even less.

A further advantage is that photo mask blanks are provided with an excellent adhesion of the first film on the substrate and/or of films on each other. Furthermore, the method is advantageously highly reproducible, such that a high stability of the optical specifications both inter and intra plate are achieved.

Preferably a gas is used to produce the ions of the first ion beam. The ions of the first ion beam preferably are or comprise rare gas ions, e.g. argon or xenon, because of their different momentum transfer function.

According to a preferred embodiment, a three grid ion extraction grid together with controllable radio frequency power plasma heating provides a separate adjustment of energy and current of the extracted ions within the construction limits. An extraction optical system provides accelerating, directing and/or focusing of the first particle or ion beam on its way to said target.

Preferably the distribution of the sputtered target atoms is adjustable by regulating parameters of the first particle beam, e.g. the incident angle, energy, current and/or mass of the particles or ions. By adjusting or controlling said parameters of the first particle beam, purity, chemical composition, surface condition and/or micro grain size of the target material are adjustable or controllable.

Furthermore the geometrical orientation of the substrate relative to the target, in particular the angle of incidence of the sputtered target atoms is adjustable. Adjusting these parameters the fundamental film growth can be influenced to optimize for stress, homogeneity and optical parameters.

Preferably the assist source and the deposition source are different sources, but are equivalently and/or independently adjustable. By this, the first and second particle beams are separately controllable and/or comprise different particles and/or have different particle energies.

Preferably, a deposition rate of >0.01 nm/sec or >0.05 nm/sec and/or <5 nm/sec, <2 nm/sec, <0.5 nm/sec or <0.3 nm/sec, most preferably in the range of about 0.1 nm/sec ± 50% is provided. At first sight this might appear uneconomic, but on the other hand the low deposition rate allows a very precise control of film thickness both by time and in situ control. In particular for phase shifting and EUV photo mask blanks this is advantageous, as a very precise control of film- or period thickness is provided such that the required phase angle and a high reflectivity are achieved. Furthermore a homogeneity of the peak reflection of smaller than ± 1% and a homogeneity of the center wavelength of smaller than ± 0.1 nm over the whole area of the photo mask blank is achieved.

According to a preferred embodiment, the substrate is conditioned by irradiating the second particle beam before the first film is deposited. In this case a low energy ion beam, e.g. <100 eV or <30 eV is utilized as second particle beam. The energy of the second ion beam is adjusted to a value at which the substrate surface is not damaged by sputtering, but organic impurities, present at the surface, are cracked. Particularly, the energy of the ions of the second particle beam, is higher than the chemical binding energies of the impurities. Preferably, this physical cleaning effect is chemically intensified by providing one or more reactive gases present in the vacuum chamber, for example oxygen, at least for some time during the treatment. Advantageously, the adhesion of the first film on the substrate and/or the films on each other and the defect density are improved.

Alternatively or additionally to said conditioning of the surface, one or more of the films are doped by the second particle beam. Preferably a doping material which is available in gaseous form is used. According to the requirements that gas is used in its original state, ionized by the plasma inside the source or even accelerated towards the photo mask blank. Particularly in this case, the geometry and/or the incidence angle of the second particle beam are adjustable and/or controllable.

Preferably, one or more of the films are doped independently, even when they are sputtered from the same target. So for example two films of the same target material are deposited and either only one film is doped or both films are independently doped, e.g. with different doping materials or doping parameters.

In a preferred embodiment, the last or top layer of a chrome binary mask is optimized for reflection by doping while one or more other films are differently doped, e.g. to adjust and optimize the optical density, the etch time, the adhesion, the reflectance and/or other features. E.g. the reflection of an anti-reflective coating can be decreased.

On the other hand, the reflectance of one or more reflecting layers of a EUV photo mask blank can be increased and/or homogenized by the treatment with the second particle beam.

In a further preferred embodiment, the substrate and/or one, several or all of the films are flattened or smoothened by irradiating with said second particle beam. Preferably a step of irradiating the photo mask blank by said second particle beam is carried out after one or more films are deposited. Flattening or smoothening one or more of the films is particularly advantageous for EUV photo mask blanks as EUV reflectance significantly depend on the interface roughness of the multi-layer stack which is, in particular reduced.

EUV Photo Mask Blank (Example A)

On the substrate is a high reflective multi-layer stack comprising bi-layers or alternating films of Molybdenum and Silicon. For clearness, only the first bi-layer directly contacting the substrate is denoted. Each layer pair or film pair has a thickness of 6.8 nm and the fraction of Molybdenum is 40%, resulting in a total thickness of 272 nm of the Mo/Si multi-layer stack. The multi-layer stack represents an EUV mirror and is protected by a 11 nm Silicon capping layer or film which is deposited on top of the multi-layer stack.

On top of the Silicon capping layer an SiO_2 buffer layer with a thickness of 60 nm is deposited. Further on top of the buffer layer an absorber layer stack comprising an anti-reflective chrome bi-layer system with a thickness of 70 nm is provided. The absorber layer stack is consisting of two chrome layers.

For manufacturing a structured photo mask from the EUV photo mask blank, the absorber layer stack is structured and partially removed by photo lithography. The buffer layer allows a repair of the structured buffer layer without damage of the multi-layer stack mirror underneath.

Deposition Parameters for Example A

The very low deposition rate of the method according to the invention allows very precise control of the layer thickness. This is highly advantageous, as particularly, the layers of the multi-layer stack mirror are only a few nm thick. The layers can be deposited with a very controlled and reproducible and, therefore equal thickness of each bi-layer. It was found, that with reduced deposition parameters as described in the following, the precision is further increased.

Argon is used as the sputter gas with 10 sccm and the energy of the primary Argon ions in the first ion beam is 600 eV. The current of the first ion beam is set to about 150 mA. To obtain a pure first ion beam beam, in the deposition source the background pressure is 2e-8 Torr and the partial pressure of Argon is set to 1e-4 Torr.

Molybdenum, silicon and chrome targets are used for the deposition of the molybdenum films Silicon and SiO_2 films and chrome films respectively.

The SiO_2 buffer layer is doped by the second ion beam comprising oxygen ions with the assist ion source using an oxygen flow of 15 sccm during and/or after the deposition of the buffer layer.

The top layer of the absorber layer pair is doped by the second ion beam using an oxygen flow of 8 sccm to reduce the reflection of the top chrome layer.

Measurement Results of Example A Homogeneity

The results of normal incidence reflectivity measurements using syncrotron radiation at Physikalisch Technische Bundesanstalt (PTB) in Berlin, Germany, can be shown in a figure. Two scans are made. One along the x-axis and one along the y-axis of the photo mask blank

being a square 6-inch plate. Each scan consists of 10 measurement points.

The homogeneity of the reflection in a plot of the measured reflection as a function of the location on the 6-inch plate along the x-axis and y-axis can be shown.

The homogeneity of peak reflection in a plot of the measured center wavelength as a function of the location on the 6-inch plate along the x-axis and along the y-axis can be shown.

The homogeneity of the peak reflection is better than ±0.2% and the homogeneity of the center wavelength is better than ±0.02 nm over the whole area of the photo mask blank.

The results of the reflection measurements of all 20 measurement points of the two scans along the x-axis and y-axis can be shown together in one plot. The reflection as a function of the wavelength in nm is plotted and it can be seen that the homogeneity is that excellent, that the 20 curves are nearly not distinguishable in that plot.

A transmission electron microscopy image of a cross section of a portion of the photo mask blank can be made. The substrate and the multi-layer stack are shown. All layers have very smooth surfaces and no systematic error is discernible. This demonstrates the excellent homogeneity and reproducibility of the layers or films deposited and treated.